SECTION 15975 - CONTROL SYSTEMS AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units that are not supplied with factory-wired controls.

1.3 SYSTEM DESCRIPTION

A. Control system consists of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories connected to controllers to operate mechanical systems according to sequences of operation indicated or specified.

1.4 SEQUENCE OF OPERATION

A. VAV SYSTEM PRIMARY AIR UNITS AHU 1,2,3,4

1. Each AHU is programmed through its Extended Digital Controller to run continuously during the occupied cycle, and be off during the unoccupied cycle. Selected room sensors shall cycle the unit during unoccupied periods at a reduced night setback temperature.
2. The outside air damper is positioned to admit 25% minimum fresh air quantities when the fan is operating
3. The fan discharge temperature is controlled at 55 deg F (13 deg C) (adj). The discharge temperature is controlled by modulating the heating coil valve, and the mixing dampers in sequence.
4. When the outdoor air temperature is greater than the return air temperature, the mixing dampers shall return to minimum position, and the cooling valve shall modulate open to control the discharge temperature at setpoint.

5. The system static pressure is controlled through the DDC controller by a static pressure transmitter located just prior to the last box in the longest duct run. The DDC controller is programmed to control the static pressure at 1 in. w.g. (248 Pa) by adjusting the supply fan speed and return fan speed through variable speed drives. A static pressure high limit in the supply fan discharge prevents the static pressure from exceeding 3 in w.g. (746 Pa). Final static pressure setpoint shall be set by test and balance contractor.
6. The digital controller shall modulate the steam injection humidifier valve to control the return air humidity at setpoint. A high limit humidity sensor downstream of the humidifier shall override the return air humidity sensor if the discharge humidity goes above 85%. The humidifier will only operate when the air handling unit is running.
7. On indication of smoke in the supply duct, or a fire alarm in the space served by this unit, the fire alarm system contacts shall stop the supply fan. The outdoor air damper shall close.
8. A manual reset freeze protection thermostat located downstream of the heating coil stops the fan, closes the outdoor air damper, and alarms at the operator workstation if any part of the 16 foot (4800 mm) sensing element senses air below its setpoint of 40 deg. (4 deg C) (adj).
9. A differential pressure switch across the pre-filter and across the high efficiency filter shall indicate status to the operator workstation.
10. A gas monitor/transmitter in AHU-1 mixing box shall reverse position of AHU-1 & –2 outside air intake dampers when nitrogen dioxide levels exceed 3 ppm (3 mg/m^3) (adj).

B. VAV/CV BOXES WITH REHEAT COILS

1. A wall mounted sensor, with adjustment, allows the digital VAV /CV controller to modulate the reheat coil valve, with the box damper at 30% minimum air flow to provide heating to the space and satisfy the space setpoint. As the space temperature rises, the coil valve is modulated closed, and the box damper modulates open beyond its minimum position. The VAV controller shall be accessed through the hand held device at the temperature sensor.
2. The box controls shall be furnished to the box manufacturer for factory mounting. The mounting costs shall be the responsibility of the box manufacturer.

C. CABINET HEATERS/ UNIT HEATERS

1. Electric thermostat opens the 2-way heating valve upon a call for heat. A strap-on aquastat located downstream of the heating valve cycles the unit fan when heat is sensed in the line downstream of the valve.

D. HEATING SYSTEM

1. An Extended Digital Controller operates the heating water pumps and alternates the lead pump on every other start-up. Selected standby pump automatically starts upon failure of the lead pump, and an alarm is indicated at the operator workstation. The lead pump runs continuously whenever the outdoor air temperature is below 65 deg F (18 deg C). Hot water supply and return temperatures will also be monitored by the system.
2. A 3-way control valve modulates the boiler water and the hot water return to control the hot water supply temperature at setpoint. The hot water supply setpoint will be reset by the outdoor air temperature according to the following adjustable reset schedule:

Outdoor air	Hot water supply
20 °F (-7 °C)	200 oF (93 °C)
50 °F (10 °C)	140 oF (60 °C)

E. COOLING SYSTEM

1. The extended digital controller shall enable the chiller to start above 50 deg F (10 deg C) (adj.) The integral chiller controls shall control the chilled water supply temperature at setpoint.
2. A flow switch, provided and wired by the temperature controls contractor shall be proven before the chiller is allowed to operate.
3. A fault indication from the chiller controls shall indicate through the extended digital controller to the central system.
4. Pump: The chilled water pump shall be allowed to operate whenever the chiller operates and shall run for a minimum of 15 minutes after the chiller is stopped.
5. When the new chiller is operating at approximately 80%, as measured through current transmitters to the extended digital controller, and more cooling is needed, the existing chilled water pump will start. When flow is proven, the existing chiller will start to meet the cooling needs of the building. When the new chiller has backed off to about 50% capacity, the existing chiller will be de-activated and allowed to pump down. The existing chilled water pump will run for at least 15 minutes before stopping. The existing chilled water pump and chiller will run for a minimum of 1 hour before being allowed to cycle off.

F. GARAGE VENTILATION

1. A carbon monoxide sensor mounted in the ambulance garage where shown, will open the motorized intake damper and start EF-7 when the carbon monoxide detector senses levels above 25 ppm (29

mg/m^3) (adj) and will shut damper and shut down EF-7 when carbon monoxide levels fall below 5 ppm (4 mg/m^3) (adj). “Off” setpoint may be set lower to avoid frequent cycling.

G. CRAWL SPACE VENTILATION

1. In each addition, both north and south, a wall mounted electric humidistat will start the wall fan and open the motorized sidewall damper when humidity levels are above the 40% relative humidity (adj).

H. RELIEF DAMPERS

1. New relief dampers in the existing hospital walls will be provided with pneumatic actuators and tied into the same control signals as the existing adjacent dampers. New and existing relief dampers in exterior walls shall close down to 10% open when outside air is below 35^{o}F (2^{o}C) (adj).

I. FIRE/SMOKE DAMPERS

1. Fire/Smoke dampers with 24 volt low voltage actuation shall be provided and installed by others. Temperature Control contractor shall connect wiring to shut the F/SD’s upon an alarm from the fire alarm system.

1.5 SUBMITTALS

A. General: Submit each item in this Article according to the Conditions of the Contract and Division 1 Specification Sections.

B. Product Data for each type of product specified. Include manufacturer's technical Product Data for each control device furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, installation instructions, and startup instructions.

1. Schematic flow diagram showing fans, pumps, coils, dampers, valves, and control devices.
2. Each control device labeled with setting or adjustable range of control.
3. Diagrams for all required electrical wiring. Clearly differentiate between factory-installed and field-installed wiring.
4. Details of control panel faces, including controls, instruments, and labeling.
5. Written description of sequence of operation.

6. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
7. Listing of connected data points, including connected control unit and input device.
8. System graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations.
9. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
10. Software description and sequence of operation.

E. Wiring diagrams detailing wiring for power, signal, and control systems and differentiating clearly between manufacturer-installed and field-installed wiring.

F. Samples of each type of furnished thermostat cover according to requirements of Division 1.

G. Maintenance data for control systems equipment to include in the operation and maintenance manual specified in Division 1. Include the following:

1. Maintenance instructions and spare parts lists for each type of control device and compressed-air stations.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

H. Field Test Reports: Procedure and certification of pneumatic control piping system.

I. Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences.

1.6 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced Installer specializing in control system installations.

B. Manufacturer Qualifications: Engage a firm experienced in manufacturing control systems similar to those indicated for this Project and that have a record of successful in-service performance.

C. Startup Personnel Qualifications: Engage specially trained personnel in direct employ of manufacturer of primary temperature control system.

D. Comply with NFPA 90A.

E. Comply with NFPA 70.

F. Coordinate equipment selection with Division 16 Section "Fire Alarm Systems" to achieve compatibility with equipment that interfaces with that system.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Store equipment and materials inside and protected from weather.

B. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping control devices to unit manufacturer.

1.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed, are packaged with protective covering for storage, and are identified with labels clearly describing contents.

B. Replacement Materials: Provide one replacement diaphragm or relay mechanism for each unique pneumatic damper motor, valve motor, controller, thermostat, and positioning relay.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Direct Digital Control (DDC) Systems and Components: (Match existing – Johnson Controls Metsys system version 9.01).
   a. Johnson Controls, Inc.; Controls Group.

2.2 CONTROL PANELS

A. Local Control Panels: Unitized cabinet with suitable brackets for wall or floor mounting, located adjacent to each system under automatic control. Provide common keying for all panels.

1. Fabricate panels of 0.06-inch- (1.5-mm-) thick, furniture-quality steel, or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock, with manufacturer's standard shop-painted finish and color.
2. Panel-Mounted Equipment: Temperature and humidity controllers, relays, and automatic switches; except safety devices. Mount devices with adjustments accessible through front of panel.
3. Door-Mounted Equipment: Flush-mount (on hinged door) manual switches, including damper-positioning switches, changeover switches, thermometers, and gages.
4. Graphics: Color-coded graphic, laminated-plastic displays on doors, schematically showing system being controlled, with protective, clear plastic sheet bonded to entire door.

B. Alarm Panels: Indicating light for each alarm point, single horn, ACKNOWLEDGE switch, and TEST switch, mounted in hinged-cover enclosure.

1. Alarm Condition: Indicating light flashes and horn sounds.
2. ACKNOWLEDGE Switch: Horn silent and indicating light steady.
3. Second Alarm: Horn sounds and indicating light steady.
4. Alarm Condition Cleared: System reset and indicating light extinguished.
5. Contacts in alarm panel allow remote monitoring by independent alarm company.

2.3 SENSORS

A. Electronic Sensors: Vibration and corrosion resistant, for wall, immersion, or duct mounting as required.

1. Resistance Temperature Detectors: Platinum.
   a. Accuracy: Plus or minus 0.2 percent at calibration point.
   b. Wire: Twisted, shielded-pair cable.
   c. Insertion Elements in Ducts: Use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft. (1 sq. m).
   d. Averaging Elements in Ducts: Use where ducts are larger than 9 sq. ft. (1 sq. m) or where prone to stratification, length as required.
   e. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches (64 mm).
   f. Room Sensors: Match room thermostats, locking cover.
   g. Outside Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
   h. Room Security Sensors: Aspirating type wall box with stainless-steel cover plate and insulated back and security screws.

2. Humidity Sensors: Bulk polymer sensor element.
   a. Accuracy: 5 percent full range with linear output.
   b. Room Sensors: With locking cover matching room thermostats, span of 25 to 90 percent relative humidity.
   c. Duct and Outside Air Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.

3. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, temperature compensated.
   a. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
   b. Output: 4 to 20 mA.
   c. Building Static-Pressure Range: 0 to 0.25 inch wg (0 to 62 Pa).
   d. Duct Static-Pressure Range: 0 to 5 inches wg (0 to 1243 Pa).

4. Pressure Transmitters: Direct acting for gas, liquid, or steam service, range suitable for system, proportional output 4 to 20 mA.

5. Carbon Monoxide Sensors:
   a. Output: 4 to 20mA
   b. Range: 0 to200 ppm (0 to 230 mg/m^3)
   c. Temperature range: 0 to 125 deg F (-18 to 52 deg C)
   d. Maximum response time: 2-1/2 minutes
   e. Solid State sensors with 3 year minimum life

6.. Gas Monitor/Transmitter:
   a. Output: 4 to 20mA
   b. Range: 0 to 10 ppm (0 to 9 mg/m^3)
   c. Temperature range: 32 to 104 deg F (0 to 40 deg C)
   d. Accuracy: 3%
   e. Relay setpoint: 3 ppm (3 mg/m^3)
   f. Solid State sensors with 3 year minimum life
   g. Enclosure: Mount in stainless steel aspirated box for inside air handling unit

C. Equipment Operation Sensors: As follows:

1. Status Inputs for Fans: Differential-pressure switch with adjustable range of 0 to 5 inches wg (0 to 1243 Pa).
2. Status Inputs for Pumps: Differential-pressure switch piped across pump with adjustable pressure-differential range of 8 to 60 psi (55 to 414 kPa).
3. Status Inputs for Electric Motors: Current-sensing relay with current transformers, adjustable and set to 175 percent of rated motor current.

D. Valve/Damper Position Indication: Potentiometer mounted in enclosure with adjustable crank-arm assembly connected to damper to transmit 0 to 100 percent valve/damper travel.

E. Water-Flow Switches: Pressure-flow switches of bellows-actuated mercury or snap-acting type, with appropriate scale range and differential adjustment, with stainless-steel or bronze paddle. For chilled-water applications, provide vaporproof type.

2.4 STANDALONE DDC PANELS (NETWORK CONTROL UNIT)

A. General: Standalone DDC panels shall be microprocessor based, multi-tasking, multi-user, real-time digital control processors. Each standalone DDC panel shall consist of modular hardware with plug-in enclosed processors, communication controllers, power supplies, and input/output modules. A sufficient number of controllers shall be supplied to fully meet the requirements of this specification and the attached point list.

B. Memory: Each DDC panel shall have sufficient memory to support its own operating system and databases including:
1. Control processes
2. Energy Management Applications
3. Alarm Management
4. Historical/Trend Data for all points
5. Maintenance Support Applications
6. Custom Processes
7. Operator I/O
8. Dial-Up Communications
9. Manual Override Monitoring

C. Surge and Transient Protection: Isolation shall be provided at all network terminations, as well as all field point terminations to suppress induced voltage transients consistent with IEEE Standard 587-1980.

D. Powerfail Restart: In the event of the loss of normal power, there shall be an orderly shutdown of all standalone DDC panels to prevent the loss of database or operating system software. Non-Volatile memory shall be incorporated for all critical controller configuration data, and battery back-up shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.

E. Upon restoration of normal power, the DDC panel shall automatically resume full operation without manual intervention.

F. Should DDC panel memory be lost for any reason, the panel will automatically receive a download via the local area network, phone lines,

or connected computer. In addition, the user shall have the capability of reloading the DDC panel via the local area network, via the local RS-232C port, or via telephone line dial-in.

2.5 SYSTEM SOFTWARE FEATURES

A. General
1. All necessary software to form a complete operating system as described in this specification shall be provided.
2. The software programs specified in this section shall be provided as an integral part of the DDC panel and shall not be dependent upon any higher level computer for execution.

B. Control Software Description:
1. Pre-Tested Control Algorithms: The DDC panels shall have the ability to perform the following pre-tested control algorithms:
a. Two Position Control
b. Proportional Control
c. Proportional plus Integral Control
d. Proportional, Integral, plus Derivative Control
e. Automatic Control Loop Tuning

2. Equipment Cycling Protection: Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.

3. Heavy Equipment Delays: The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.

4. Powerfail Motor Restart: Upon the resumption of normal power, the DDC panel shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operation.

C. Energy Management Applications:

1. DDC Panels shall have the ability to perform any or all of the following energy management routines:
a. Time of Day Scheduling
b. Calendar Based Scheduling
c. Holiday Scheduling
d. Temporary Schedule Overrides
e. Optimal Start
f. Optimal Stop
g. Night Setback Control

h. Enthalpy Switch Over (Economizer)
i. Peak Demand Limiting
j. Temperature Compensated Load Rolling
k. Fan Speed/CFM Control
l. Heating/Cooling Interlock
m. Cold Deck Reset
n. Hot Deck Reset
o. Hot Water Reset
p. Chilled Water Reset
q. Condenser Water Reset
r. Chiller Sequencing

2. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow operator customization. Programs shall be applied to building equipment as described in the Execution portion of this specification.

D. Custom Process Programming Capability: DDC panels shall be able to execute custom, job-specific processes defined by the operator, to automatically perform calculations and special control routines.

1. Dynamic Data Access: A single process shall be able to incorporate measured or calculated data from any and all other DDC panels on the local area network. In addition, a single process shall be able to issue commands to points in any and all other DDC panels on the local area network.

2. Advisory/Message Generation: Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device, buffer the information in a follow-up file, or cause the execution of a dial-up connection to a remote device such as a printer.

3. Custom Process Documentation: The custom control programming feature shall be self-documenting. All interrelationships defined by this feature shall be documented via graphical flowcharts and English language descriptors.

E. Alarm Management: Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each DDC panel shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall the DDC panel's ability to report alarms be affected by either operator

activity at a PC Workstation or local I/O device, or communications with other panels on the network.

1. Point Change Report Description: All alarm or point change reports shall include the point's English language description, and the time and date of occurrence.

2. Prioritization: The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three priority levels shall be provided. Each DDC panel shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point. The user shall also be able to define under which conditions point changes need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date.

3. Report Routing: Alarm reports, messages, and files will be directed to a user-defined list of operator devices or PC disk files used for archiving alarm information. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.

4. Alarm Messages: In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 65-character alarm message to more fully describe the alarm condition or direct operator response.

a. Each standalone DDC panel shall be capable of storing a library of at least 250 Alarm Messages. Each message may be assignable to any number of points in the panel.

5. Auto-Dial Alarm Management: In Dial-up applications, only critical alarms shall initiate a call to a remote operator device. In all other cases, call activity shall be minimized by time-stamping and saving reports until an operator scheduled time, a manual request, or until the buffer space is full. The alarm buffer must store a minimum of 50 alarms.

6. Transaction Logging: Operator commands and system events shall be automatically logged to disk in Personal Computer industry standard database format. Operator commands initiated from Direct-connected workstations, dial-up workstations, and local DDC panel Network Terminal devices shall all be logged to this transaction file. This data shall be available at the Operator Workstation. A utility shall be provided to allow the user to search the transaction file using standard

database query techniques, including searching by dates, operator name, data point name, etc. In addition, this transaction file shall be accessible with standard third party database and spreadsheet packages.

F. Historical Data and Trend Analysis: A variety of Historical data collection utilities shall be provided to automatically sample, store, and display system data in all of the following ways:

1. Continuous Point Histories: Standalone DDC panels shall store Point History Files for all analog and binary inputs and outputs.

a. The Point History routine shall continuously and automatically sample the value of all analog inputs at half hour intervals. Samples for all points shall be stored for the past 24 hours to allow the user to immediately analyze equipment performance and all problem-related events for the past day. Point History Files for binary input or output points and analog output points shall include a continuous record of the last ten status changes or commands for each point.

2. Control Loop Performance Trends: Standalone DDC panels shall also provide high resolution sampling capability in one-second increments for verification of control loop performance.

3. Extended Sample Period Trends: Measured and calculated analog and binary data shall also be assignable to user-definable trends for the purpose of collecting operator-specified performance data over extended periods of time. Sample intervals of 1 minute to 2 hours shall be provided. Each standalone DDC panel shall have a dedicated buffer for trend data, and shall be capable of storing a minimum of 5000 data samples.
a. Data Storage and Archiving: Trend data shall be stored at the Standalone DDC panels, and uploaded to hard disk storage when archival is desired. Uploads shall occur based upon either user-defined interval, manual command, or when the trend buffers become full. All trend data shall be available in disk file format compatible with Third Party personal computer applications.

G. Runtime Totalization: Standalone DDC panels shall automatically accumulate and store runtime hours for binary input and output points as specified in the Execution portion of this specification.

1. The Totalization routine shall have a sampling resolution of one minute or less.

2. The user shall have the ability to define a warning limit for Runtime Totalization. Unique, user-specified messages shall be generated when the limit is reached.

H. Analog/Pulse Totalization: Standalone DDC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.

1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g. KWH, gallons, KBTU, tons. etc.).

2. The Totalization routine shall have a sampling resolution of one minute or less.

3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

I. Event Totalization: Standalone DDC panels shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly, or monthly basis.

1. The Event Totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.

2. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

2.6 EXTENDED DIGITAL CONTROLLER FOR ALL AIR HANDLING UNITS, COOLING SYSTEM, HEATING SYSTEM, AND PUMP CONTROL

A. The extended digital controller will be capable of operating as a stand-alone direct digital controller or of being networked as part of the facility management system. The controller shall be a microprocessor-based, multi-tasking, real-time digital control processor.

B. The extended digital controller shall be fully custom field programmable to meet the specified applications, but be flexible enough to accommodate future applications. Points unused in the control scheme shall be capable of being used for non-critical supervisory or control applications by the rest of the network.

C. The extended digital controller shall have the following features as a minimum:

1. Real time clock with optimal start/stop for emergency stand alone situations.

2. Built-in RS-232C and RS-485 ports
3. Built in operator display showing operating parameters and input/output values. Outputs shall be capable of being manually overridden and operating parameters changed from the panel display.
4. All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored in EEPROM such that a power failure of any duration does not necessitate reprogramming the controller.

D. The extended digital controller shall be capable of fully proportional, PI, PID, Dual PID, on/off, or Dual on/off control.

2.7 VAV TERMINAL UNIT CONTROLLERS:

A. VAV Terminal Unit Controllers shall support, but not be limited to, the control of the following configurations of VAV boxes to address current requirements as described in the Execution portion of this specification, and for future expansion:
1. Single Duct Only (Cooling Only, or Cooling with Reheat).
2. Fan Powered (Parallel/Side Pocket, Series/On-Off Logic)
3. Dual Duct (Constant Volume, Variable Volume)
4. Supply/Exhaust

B. VAV Terminal Unit Controllers shall support the following types of point inputs and outputs:
1. Proportional Cooling Outputs
2. Box and Baseboard Heating Outputs (Proportional, or 1 to 3 Stages)
3. Fan Control Output (On/Off Logic, or Proportional Series Fan Logic)
4. The modes of operation supported by the VAV Terminal Unit Controllers shall minimally include, but not be limited to, the following:
   a. Day/Weekly Schedules
   b. Comfort/Occupancy Mode
   c. Economy Mode (Standby Mode, Unoccupied, etc.)
   d. Temporary Override Mode

C. Occupancy-Based Standby/Comfort Mode Control: Each VAV Terminal Unit Controller shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the VAV Terminal Unit Controller shall automatically select either Standby or Comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

E. Occupancy-Based Zone Lighting Control: VAV Terminal Unit Controllers shall provide an auxiliary binary output to serve as the interface to an associated lighting relay. Based upon the status of either an occupancy

sensing device, or manual wall switch, the VAV Terminal Unit Controller shall provide a contact output to automatically adjust the lighting level to accommodate occupant requirements while reducing electrical consumption. Standby/Comfort (described in the previous section) and Lighting overrides shall be served by the same occupancy override input.

F. Alarm Management: Each VAV Terminal Unit Controller shall perform its own limit and status monitoring and analysis to maximize network performance by reducing unnecessary communications.

2.8 THERMOSTATS

A. Combination Thermostat and Fan Switches: Line-voltage thermostat with 2-, 3-, or 4-position, push-button or lever-operated, fan switch.

1. Label switches "FAN ON-OFF," "FAN HIGH-LOW-OFF," "FAN HIGH-MED-LOW-OFF." Provide unit for mounting on 2-gang switch box.

B. Low-Voltage, ON-OFF Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-switch type, with either adjustable or fixed anticipation heater.

C. Line-Voltage, ON-OFF Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch type, or equivalent solid-state type, with heat anticipator, integral manual ON-OFF-AUTO selector switch; UL listed for electrical rating.

1. Equip thermostats, which control electric heating loads directly, with OFF position on dial wired to break ungrounded conductors.
2. Dead Band: Maximum 2 deg F (1 deg C).

D. Remote-Bulb Thermostats: ON-OFF or modulating type, liquid-filled to compensate for changes in ambient temperature, with copper capillary and bulb, unless otherwise indicated.

1. Bulbs in water lines with separate wells of same material as bulb.
2. Bulbs in air ducts with flanges and shields.
3. Averaging Elements: Copper tubing with either single- or multiple-unit elements, extended to cover full width of duct or unit, adequately supported.
4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
5. ON-OFF, remote-bulb thermostats with precision snap switches, with electrical ratings required by application.
6. Construct modulating, remote-bulb, potentiometer thermostats so complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.

E. Room Thermostat Construction: Manufacturer's standard locking covers.
1. Thermometer: Red-reading glass or spiral bimetal.
2. Guards: Heavy-duty, clear plastic or metal-wire, tamperproof guards.
3. Locking Covers: With only temperature indication visible.
4. Limits: Provide on heating/cooling dual-temperature thermostats, to prevent setting cooling set point below 75 deg F (24 deg C), and heating set point above 75 deg F (24 deg C).

F. Room Thermostat Accessories: As follows:

1. Insulating Bases: For thermostats located on exterior walls.
2. Thermostat Guards: Locking transparent-plastic mounted on separate base.
3. Adjusting Key: As required for device.
4. Aspirating Boxes: Where indicated for thermostats requiring flush installation.

G. Immersion Thermostat: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range and adjustable set point.

H. Airstream Thermostats: 2-pipe, fully proportional, single temperature, with adjustable set point in middle of range and adjustable throttling range, plug-in test fitting or permanent pressure gage, remote bulb, bimetal rod and tube, or averaging element.

I. Electric Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic-reset switch that trips if temperature sensed across any 12 inches (305 mm) of bulb length is equal to or below set point.
1. Bulb Length: Minimum 20 feet (6 m).
2. Quantity: 1 thermostat for every 20 sq. ft. (1.9 sq. m) of coil surface.

J. Electric High-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic-reset switch that trips if temperature sensed across any 12 inches (305 mm) of bulb length is equal to or above set point.

1. Bulb Length: Minimum 20 feet (6 m).
2. Quantity: 1 thermostat for every 20 sq. ft. (1.9 sq. m) of coil surface.

2.9 HUMIDISTATS

A. Duct-Mounted and wall mounted (crawl space)Humidistats: Electric insertion, 2-position type with adjustable 2 percent throttling range, 20 to 80 percent operating range, single- or double-pole contacts.

2.10 ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or 2-position action.
   1. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
   2. Spring-Return Motors for Valves Larger Than 2-1/2 Inches (64 mm): Size for running and breakaway torque of 150 inch-pounds (16.9 N x m).
   3. Spring-Return Motors for Dampers Larger Than 25 sq. ft. (2.3 sq. m): Size for running and breakaway torque of 150 inch-pounds (16.9 N x m).

B. Electronic Operators: Select operator for full shutoff at maximum pump differential pressure.

2.11 CONTROL VALVES

A. Control Valves: Factory fabricated, of type, body material, and pressure class indicated. Where type or body material is not indicated, make selection as determined by manufacturer for installation requirements and pressure class, based on maximum pressure and temperature rating of piping system.

B. Globe Pattern: As follows:
   1. Up to 2 inches (DN 50): Bronze body, bronze trim, rising stem, renewable composition disc, screwed ends with backseating capacity repackable under pressure.
   2. Over 2 inches (DN 50): Iron body, bronze trim, rising stem, plug-type disc, flanged ends, renewable seat and disc.
   3. Hydronic Systems: As follows:
      a. Rating: Service at 125 psi WSP (862 kPa) and 250 deg F (121 deg C).
      b. Internal Construction: Replaceable plugs and seats of stainless steel or brass.

         1) Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom of guided plugs.
         2) Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom of guided plugs.

c. Sizing: 3-psi (21-kPa) maximum pressure drop at design flow rate.
d. Flow Characteristics: 2-way valves have equal percentage characteristics; 3-way valves have linear characteristics. Select operators to close valves against pump shutoff head.

C. Butterfly Pattern: Iron body; bronze, aluminum-bronze, or stainless-steel disc; resilient, replaceable seat for service to 180 deg F (82 deg C) wafer or lug ends; extended neck.
1. Rating: Service at 125 psi WSP (862 kPa) and 250 deg F (121 deg C).
2. Sizing: 1-psi (7-kPa) maximum pressure drop at design flow rate.

D. Terminal Unit Control Valves: Bronze body, bronze trim, 2 or 3 port as indicated, replaceable plugs and seats, union and threaded ends.
1. Rating: Service at 125 psi WSP (862 kPa) and 250 deg F (121 deg C).
2. Sizing: 3-psi (21-kPa) maximum pressure drop at design flow rate, to close against pump shutoff head.
3. Flow Characteristics: 2-way valves have equal percentage characteristics; 3-way valves have linear characteristics.
4. Operators (2 Position): Synchronous motor with enclosed gear train, dual-return springs, valve-position indicator. Valves spring return to normal position for temperature protection.
5. Operators (Modulating): Self-contained, linear motor, actuator with 60-second full travel, with transformer and single-throw, double-pole contacts.

2.12 DAMPERS

A. Dampers: AMCA-rated, parallel or opposed blade design; form frames from not less than 0.1084-inch (2.8-mm) galvanized steel with mounting holes for duct mounting; damper blades not less than 0.0635-inch (1.6-mm) galvanized steel, with maximum blade width of 8 inches (203 mm).
1. Blades secured to 1/2-inch (13-mm) diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass. Ends sealed against spring-stainless-steel blade bearings. Thrust bearings at each end of every blade.
2. Operating Temperature Range: From -40 to 200 deg F (-40 to 93 deg C).
3. For standard applications as indicated, (as selected by manufacturer's sizing techniques) with optional closed-cell neoprene edging.
4. For low-leakage applications as indicated, provide parallel or opposed blade design (as selected by manufacturer's sizing techniques) with inflatable seal blade edging, or replaceable rubber

seals, rated for leakage at less than 10 cfm/sq. ft. (51 L/s/sq. m) of damper area, at differential pressure of 4 inches wg (995 Pa) when damper is being held by torque of 50 inch-pounds (5.6 N x m); test in accordance with AMCA 500.

2.13 CONTROL CABLE

A. Control systems and equipment shall be wired as per manufacturers' requirements.

2.14 VARIABLE SPEED CONTROLLERS

A. The temperature control contractor shall furnish and install variable speed drives manufactured by a single source.

B. Each variable speed controller shall have a main disconnect. Disconnect to be supplied by mechanical contractor and installed by electrical contractor.

C. Inverters shall be manufactured in the United States. To insure compatibility with future equipment, the manufacturer shall have one design to cover the full range of controllers required.

D. The variable volume inverter duty motors and variable speed drives shall be manufactured by a single source. The inverter manufacturer shall assume all warranty rresponsibilities of motors.

E. The inverter manufacturer shall have a minimum of 10 years experience in manufacturing inverters and shall have a minimum of 7 years experience with IGBT transistors used with the inverter to produce the output PWM waveform, **allowing quiet motor operation**. Inverters up to 135 RW with carrier frequencies below 12 kHz will not be acceptable. All inverters must be IGBTs.

F. The adjustable speed drive shall maintain a 120% current overload capability for 60 seconds with automatic stall prevention and voltage boost to prevent nuisance tripping during load or line side transient conditions. The adjustable speed drive shall maintain a power factor of not less than 0.95 throughout its speed range.

G. The inverters shall be rated for continuous duty at a 12 kHz carrier frequency on the motor full load currents listed below (from NEC Table 150). If derating of the inverter is necessary to run at 12 kHz, then the units must be derated and their new derated currents must equal or exceed the motor full load currents listed in the table below.

H. The Insulated Gate Bipolar Transistors (IGBTs) shall have a minimum rating of on 208/230 VAC units. The manufacturer of the inverter must have a minimum of 7 years experience in the manufacturer and use of IGBTs.

I. Enclosure: The VFD shall have a metal NEMA 1 enclosure for reduction of radio frequency and electromagnetic interference. Plastic enclosures are not acceptable. The enclosure shall be wall mount. The enclosure door shall be hinged for easy access and all internal components shall be easily accessible.

1. 12 KHz sine-coded, pulse width modulated output.
2. Overload capability of 120% for 60 seconds, 110% continuous.
3. Process follower 4-20m ADC, 0-5VDC, or 0-10VDC input.
4. An LED digital readout displaying output frequency, status, percent current, percent voltage, and response signal.
5. Current limiting circuit.
6. Adjustable acceleration and deceleration.
7. In addition to the inverter's self diagnostic features, the drive shall have a form C contact (1NO, 1NC) for remote indication of fault.
8. Customer interlock for remote starting and stopping.
9. On loss of speed reference signal, the drive shall operate at a preset minimum speed so that the inverter will not drive the fan at a speed capable of causing system problems.
10. The drive shall provide a 24 VDC open collector output signal which will indicate when the drive is running, and when the drive is at a certain preset speed.
11. The drive shall be capable of restarting into a rotating motor (as when motor is windmilling or when transferring power from bypass mode to inverter mode) by sensing the frequency of the rotating motor and starting into the motor at that frequency.
12. The drive shall have a digital keypad for performing all parameter adjustments and programming which shall include the following features:
    a. Quick setup key to allow for simple setup and expeditious startup.
    b. Manual/Off/Auto keys for selection of control mode.
    c. Fault clear/reset key.
    d. Run and stop keys for starting and stopping in manual mode.
    e. Up and Down arrow keys for adjustment of motor speed and adjustment of programming parameters.
    f. Program key for entering program mode for adjustments of parameters.
    g. Read/write key for changing parameters in program mode.
13. The drive shall have PID (set point) control.

14. The inverter shall have a DC link reactor which will reduce harmonics at the input. If a DC link reactor is not provided, an AC input line reactor or isolation transformer shall be provided.
15. The drive shall be equipped with critical frequency avoidance where it shall be capable of avoiding up to three resonant points in the mechanical system.
16. A user programmable personal lockout code shall prevent unauthorized programming of the inverter.

J. The adjustable speed drive shall have, as a minimum, the following protective features:

1. Ground fault protection.
2. Thermal motor overload relay (if inverter bypass option is used).
3. Current limit adjustable 10-100%.
4. Current limited stall prevention during acceleration, deceleration, and run conditions.
5. Automatic restart after momentary power loss or momentary overvoltage. The drive shall not restart into faults other than overvoltage, undervoltage, or overcurrent due to acceleration rate set too fast, because other faults, such as an overcurrent due to a blown transistor or a short circuit on the output, could cause damage to the inverter.
6. Fault indicators shall indicate the following fault conditions. Faults should be displayed by flashing on the LED display on the front panel of the inverter. When a fault occurs, the drive shall have built in diagnostic functions that assist in determining the cause and source of the fault. The drive shall also indicate the level of current and voltage and the frequency at the time of the fault.

a. Overcurrent during acceleration (OC1).
b. Overcurrent during deceleration (OC2).
c. Overcurrent while running (OC3).
d. Overcurrent on output (OCL).
e. Overcurrent detected at startup (OCA).
f. Overload (OL).
g. Overvoltage while deceleration (OP2).
h. Overvoltage due to power surge (OP).
i. Over temperature (OH).
j. Ground Fault (EF).
k. Emergency Stop (E).
l. Frequency Setting Fault (EFF).
m. EEPROM Abnormality (EEP).
n. EEPROM Abnormality (EEP2).
o. EEPROM Abnormality (EEP3).
p. Computer Link Abnormality (Err.t).

q. Power Supply Undervoltage (POFF).
r. DC Main Circuit Undervoltage (nOFF).

7. Current limiting DC bus fuse.
8. Phase-to-phase short circuit protection.

K. The adjustable speed drive shall have the following adjustments available under the SETUP key:

1. Acceleration - 0.1 to 3000 seconds.
2. Deceleration - 0.1 to 3000 seconds.
3. Maximum frequency range.
4. Maximum frequency (0 to 100% speed).
5. Bias and gain adjustment for 4-20mA, 0-5VDC, 0-10VDC follower. (Can be direct or indirect acting.)
6. Thermal overload adjustment (10-100%).

L. The adjustable speed drive shall be designed to operate within the following environmental and service conditions.

1. Ambient service temperature: -10 C to 40 C.
2. Ambient storage temperature: -20 C to 60 C.
3. Humidity: non-condensing to 90%.
4. Altitude to 4200 feet (1260 m).
5. Service factor: 1.1.
6. Input voltage: three phase, 208/230 VAC +/- 10% for series.
7. Input frequency: 50/60 hertz +/- 3%.

M. The adjustable speed drive shall be designed and built to the following standards:

1. U.L. listed.
2. NEMA listed.
3. IEEE 587.

N. Provide the following accessories:

1. Customer Interlock Terminal Strip - provide a separate terminal strip for connection of freeze, fire, smoke contacts, fault contact output, input reference signal, and external start command. All external interlocks shall remain fully functional whether the drive is in Hand or Auto modes. External start command shall be active when in the Auto mode only.

2. Door interlocked circuit breaker (25,000 A.I.C.) which will disconnect all input power from the drive and all internally mounted

options. The disconnect handle shall be through-the-door type, and be padlockable in the Off position. A disconnect switch is not acceptable as this will protect neither the inverter nor the motor. For multiple motor applications, the circuit breaker shall be of the thermal magnetic type per NEC.

3. Manual/Automatic Bypass Circuit:
   a. The bypass circuit shall allow the user to manually bypass the drive and transfer control of the motor across the line, running the motor at full speed. While in the bypass operation, the motor shall be protected by a circuit breaker and an overload relay. A three position selector switch which controls the bypass contactor and the drive output contactor is to be mounted on the enclosure door. When in the Inverter mode, the bypass contactor is open and the drive output contactor is closed. In the Off position, power will be removed from both the inverter and the bypass circuits. In the Bypass position, the drive output contactor is open and the bypass contactor is closed. All safety interlocks will work in both the drive and bypass modes. The contactors shall have auxiliary contacts connected to a terminal strip for indication of bypass or inverter modes. The drive shall have a two position selector switch labeled Manual/Auto. In the Manual position, the drive will only go into bypass if the Inverter/Off/Bypass switch is in the Bypass position. In the Auto position, the drive shall automatically transfer the motor across the line if the drive goes into a fault condition and will not automatically reset.

   b. A service contactor shall be provided to electrically isolate the drive while in bypass operation without having to remove power from the motor. This will allow the ability to service the drive when in bypass operation. The service contactor shall open when the drive is switched to bypass, and also be controlled by a switch which is mounted on the drive enclosure.

   c. A motor overload relay shall be provided to protect the motor in the bypass mode.

O. The adjustable frequency drive manufacturer shall have established for not less than two years prior to the bid opening, a service and repair representative in Great Falls, Montana. The local service representative shall inspect the installation, start and calibrate the drives, and provide immediate response during the one-year warranty period.

P. Provide drives equal to Toshiba Q-Flowsaver 11, Graham 2001 or Softronics G-3 Plus series.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify that conditioned power supply is available to control units and operator workstation. Verify that field end devices, wiring, and pneumatic tubing are installed before proceeding with installation.

3.2 INSTALLATION

A. Install equipment as indicated to comply with manufacturer's written instructions.

B. Install software in control units and operator workstation. Implement all features of programs to specified requirements and appropriate to sequence of operation.

C. Connect and configure equipment and software to achieve the sequence of operation specified.

D. Verify location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation. Locate 54 inches (1350 mm) above floor.
1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

E. Provide guards on thermostats in the following locations:
1. Entrances.
2. Public areas.
3. Other areas where indicated.

F. Install damper motors on outside of duct in warm areas, not where exposed to outdoor temperatures.

G. Install labels and nameplates to identify control components according to Division 15 Sections specifying mechanical identification.

H. Install hydronic instrument wells, valves, and other accessories according to Division 15 Section "Hydronic Piping."

I. Install duct volume-control dampers according to Division 15 Sections specifying air ducts.

3.3 ELECTRICAL WIRING AND CONNECTIONS

A. Install raceways, boxes, and cabinets according to Division 16 Section "Raceways, Boxes, and Cabinets."

B. Install building wire and cable according to Division 16 Section "Wires and Cables."

C. Install signal and communication cable according to manufacturers' requirements.

1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
2. Install exposed cable in raceway.
3. Install concealed cable in raceway.
4. Bundle and harness multiconductor instrument cable in place of single cables where a number of cables follow a common path.
5. Fasten flexible conductors, bridging cabinets and doors, neatly along hinge side; protect against abrasion. Tie and support conductors neatly.
6. Number-code or color-code conductors, except local individual room controls, for future identification and servicing of control system.

D. Connect electrical components to wiring systems and to ground as indicated and instructed by manufacturer. Tighten connectors and terminals, including screws and bolts, according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torquing requirements are not indicated, tighten connectors and terminals according to tightening requirements specified in UL 486A.

E. Connect manual reset limit controls independent of manual control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

F. Connect HAND-OFF-AUTO selector switches to override automatic interlock controls when switch is in HAND position.

3.4 COMMISSIONING

A. Manufacturer's Field Services: Provide the services of a factory-authorized service representative to start control systems.

B. Test and adjust controls and safeties.

C. Replace damaged or malfunctioning controls and equipment.

D. Start, test, and adjust control systems.

E. Demonstrate compliance with requirements.

F. Adjust, calibrate, and fine tune circuits and equipment to achieve sequence of operation specified.

3.5 DEMONSTRATION

A. Manufacturer's Field Services: Provide the services of a factory-authorized service representative to demonstrate and train Owner's maintenance personnel as specified below.
   1. Train Owner's maintenance personnel on procedures and schedules related to startup and shutdown, troubleshooting, servicing, and preventive maintenance.
   2. Schedule training with Owner with at least 7 days' notice.
   3. Provide minimum 8 hours operator training on data display, alarm and status descriptors, requesting data, execution of commands, and request of logs.

END OF SECTION 15975